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§1. Improvement of Compact Torus Injector for Fuelling LHD

Fukumoto, N., Nagata, M. (Univ. Hyogo),
Masamune, S., Sanpei, A. (Kyoto Inst. Tech.),
Takahashi, T., Asai, T. (Nihon Univ.),
Irie, M. (Waseda Univ.),
Miyazawa, J., Yamada, H.

The Compact Toroid (CT) injector of SPICA (SPeromak Injector using Conical Accelerator) has been developed for an advanced refueling in LHD. Through experimental results, the SPICA device has achieved CT parameters to penetrate into LHD plasmas at B = 0.8 T. However, after considering CT transport in long distance to plasma central region and CT injection into LHD plasmas at higher B, the injector performance needs to be enhanced much more.

In this fiscal year, we have conducted the experiments with a focus on surveying the basic CT parameters to clear the requirements for the improvement of the SPICA device. As the first step, the electrodes for CT acceleration were shortened to half, and then a flux conserver (FC) and a compressor, which were provided from the other CT injector, were connected to the exit of the SPICA. The preliminary tests indicated that CT plasmas could not move into the FC owing to worse-than-expected CT deceleration through the compressor. Thus we designed and made a new FC to be directly connected to the SPICA device without the compression part. The ratio of inner diameter to length was determined at 720/400 based on an obtained equilibrium solution for sphromak. The experimental setup with the new FC is shown in Fig. 1. PIN diodes were mounted at port P1-P4 for the observation of CT transit to calculate CT speed. In the FC, the He-Ne laser interferometer measured the line-averaged electron density of a CT plasma. The magnetic probe arrays also provide magnetic field profile measurements of the CT.

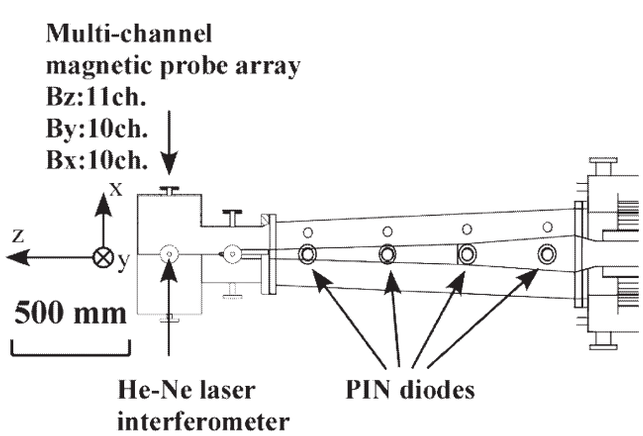

Fig. 1. Measurement system for SPICA device and flux conserver.

Figure 2 shows the typical time evolution of PIN diode signals and the CT density for the current fed through the bias poloidal coil I_{bias} = 210 A, the charging voltage on the formation bank $V_{form.}$ = 8 kV, the voltage on the acceleration bank $V_{acc.}$ = 12 kV. Here, CT speeds are estimated at 126 km/s between VL2 and VL3 (P2 and P3) and 56 km/s between VL3 and VL4 (P3 and P4). The peaked CT density is 9.6×10^{20} m^{-3} in the FC. In addition, the magnetic field profile in the FC indicated a typical spheromak configuration. In these experiments the noise in observed signals, which occur when CT plasmas eject from the SPICA device, are extremely lower than those in previous experiments. This is considered to be due to change of acceleration current pathway at the time of separation of the current and the CT plasma ejecting from the muzzle of the SPICA. Therefore we have investigated the adverse effects of long electrodes in the experiments with different length accelerators. Decrease of noise level allows us to operate the SPICA device at higher voltage on the CT accelerator bank, leading to enhancement of CT parameters.

On the measurement system, we have modified the He-Ne interferometer to add one more channel in order to investigate the density decay in a CT plasma moving through the accelerator into the FC. As future works, we will measure CT parameters and magnetic field profiles to investigate the dependence on the operation parameters (the trigger timings of gas-puffing, formation and acceleration, the duration of the gas-puffing, the bias poloidal (BP) magnetic field, and the charging voltages of the formation and acceleration capacitor banks) on the any stages of CT formation, acceleration, ejection and transportation. Moreover, a BP coil will be added on the SPICA injector. Various systematic scan of the CT operation parameters will be conducted to find suitable positions of the BP coil and the gas puff valves for CT formation and acceleration. The SPICA injector will be effectively improved through the series of experiments.

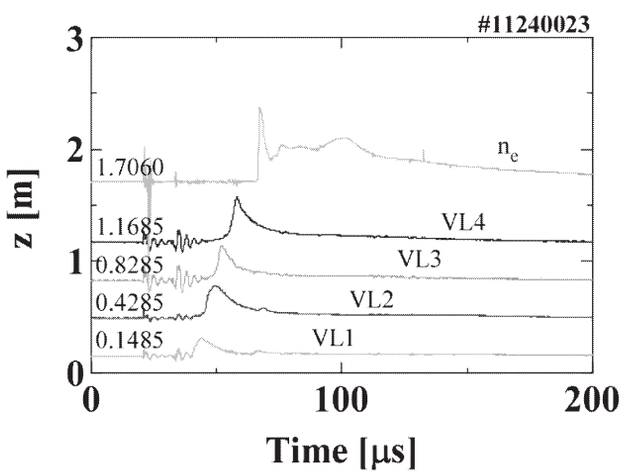

Fig. 2. Typical evolution of PIN diode signals in the acceleration region and line-averaged electron density in the FC.